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Dear Mr Alexander

Properties of Accoya™ and its suitability for use in an exterior balcony structure

We understand that you are conducting technical due diligence on Accoya™ which is the trademark name for permeable timber that is acetylated using the Titan wood patented process to a weight percent gain (WPG) of 20% throughout the cross section and its suitability for use as in exterior balcony structures on residential buildings in the UK. On the 19 July 2006 I wrote to you detailing our view on the use of this material in window joinery. You have requested that we provide you with comment regarding the suitability of the material for the application when laminated with an exterior grade polyurethane adhesive and used in balconies. The balconies are out of ground contact and are factory coated with high performance three coat water-based opaque coating. You have asked us to comment on:

- The durability class of acetylated timber compared to other timber species commonly used for exterior joinery applications
- The dimensional stability compared to timber species commonly used for exterior joinery applications
- The particular structural and glue laminated performance of the substrate
- The relation of durability class to compliance of products to the British Standards for life expectancy

In our letter dated the 19 July 2006 concerning the suitability of acetylated wood for use in exterior joinery we commented in some detail about the durability of wood and its specification. Some of that is worth repeating here with a focus on the particular application.

Specification of timber for a balcony

The suitability of a timber species for use in external joinery (e.g. balcony) in the UK must first consider the natural durability of the chosen timber species (EN 350-2: 1994) and note that the intended end use is Hazard Class 3 (EN 335-1: 1992). EN 460 compares the requirements of Hazard Class with the natural durability and indicates whether natural durability is sufficient for the end use or whether preservative treatment is required. The European Standards related to specifying preservative treated timber, EN351-1 (1996) and EN 351-2 (1996), have been published for 10 years. They require the specification to be written in terms of the results of the treatment process. A required penetration of the preservative into the wood and the retention (concentration) of preservative within a defined zone (the analytical zone) of the treated timber is specified. EN351-1 (1996) lists nine options that can be used to specify penetration. The retention is specified in terms of the concentration of preservative formulation found to be effective in a series of standard biological test methods laid down in the European Standard EN599-1 (1997). The treater has to demonstrate to the specifier that the required level of treatment has been achieved. This can be done by obtaining a representative sample of the treated timber, randomly selected according to the International Standard ISO 2859-1 (1999), and analysing for penetration and retention. EN 351-2 (1996) prescribes methods of obtaining the samples for analysis from the selected components. In all cases the retention of wood preservative is described as the amount analysed in the analytical zone.

BS 8417 (2003) sets out a framework for UK specifiers to interpret the European standards and to base specifications on penetration and retention requirements thought to reflect what the old process specifications actually achieved. Provision is made in the document for the range of traditional preservatives with recommended penetration/retention combinations for different timber types, end uses and service life requirements. These are based on best estimates of what has been achieved in practice. Guidance is also given for new preservatives whose performance is demonstrated by testing according to EN599-1 (1997) but which have little or no evidence from longer term tests or service data.

There are no Standards specifically written to give guidance on or requirements for specification of acetylated timber. A permeable timber that is acetylated throughout the cross section to 20% WPG offers an opportunity for consideration as an external balcony substrate for high quality fully factory finished balcony.

Biological durability

What are the requirements for a balcony?

In BS 8417 (2003) exterior joinery is noted as Hazard Class 3 (EN 335-1: 1992) application and a 15, 30 or 60 year service life is satisfied by choosing as a minimum a timber of natural durability class 4, 3 or 2 respectively (EN 350-1: 1994). In addition, the service factor based on safety and economic factors is Class D where collapse of structures would constitute a serious danger to persons or property thus natural durability or preservative treatment is essential.

What is natural durability?

Natural durability refers to the ability of a wood species to endure, or resist deterioration, by virtue of its inherent properties. In the UK this typically refers to the ability to resist attack from wood-destroying fungi. This ability to withstand fungal attack is assessed in laboratory and field experiments in line with European standard tests, which for natural durability include long running ground contact field trials (EN 252: 1990). In the UK the national field trials for determining natural durability have been managed by BRE for almost 80 years. The assessments classify the heartwood of each timber species into one of five different durability classes depending on their performance. The data is presented in BRE Digest 429 (1998).

Digest 429 or EN 350-2	**Durability class**
Western red cedar (*Thuja plicata*) old growth North America	2 (durable)
American white oak (*Quercus alba*)	2 (durable)
Siberian larch (*Larix siberica*)	3 (moderately durable)
Sapele (*Entandrophragma cylindricum*)	3 (moderately durable)
Douglas fir (*Pseudotsuga menziesii*)	3-4 (moderately durable to slightly durable)
Scots pine (*Pinus sylvestris*)	4 (slightly durable)
Acetylated wood*	1 (very durable)
Preservative-treated wood[†]	1 (very durable)

* Sources of information are consider later in this document

† The preservative treatment of ‘not durable’ or ‘slightly durable’ wood to a retention at the critical value (CV) or above derived from BS EN 599-1 enhances the wood to maximum durability as the <3% weight loss criteria in the test is equivalent to delivering durability class 1 ‘very durable’

There are a wide range of references related to the durability of acetylated wood that show that at WPG of 20% the wood is resistance to attack by wood destroying organisms (fungi and insects) and is classed as durability class 1. Sources of information relating to the durability of acetylated wood include an SHR report to Titanwood (2006) which is an extract from the European collaborative AIR project (1993-1995) and assesses the durability of acetylated wood (beech, pine and poplar) to brown and white rot fungi, soft rot fungi, blue stain in service and field trials. EN 113 (1997) reveals that data from tests conducted with leaching pre-conditioning (EN 84: 1997) were similar to those without – concluding that acetylation is fixed. For two of the brown rot fungi tested at WPG of 15% and above the three timber species were classified as durability class 1. At a WPG of 20% the specimens had less than 3% weight loss during the 16 week exposure period of the test. The other brown rot fungi (*Poria placenta*) revealed weight losses of about 5% at a WPG of 20%. For the white rot fungi tested the weight loss for acetylated beech and poplar during the test reached zero at a WPG of 12%.

BRE tests conducted in collaboration with the University of Wales, Bangor (Suttie et al 1997 and 1998), Hill (2006) and Westin et al (2004) present durability data for acetylated wood including in ground contact field tests. In addition actual products in service in the field as canal linings. We would expect the performance in out-of-ground applications such as a balcony where the moisture risk is significantly reduced and the presence of some wood destroying organisms does not occur to be significantly better.

Dimensional stability

What are the requirements for balconies?

BS EN 942 (1996) notes in informative annex D dimensional movement as a serviceability aspect (small, medium or large) of timber for joinery and the suitability of timber species for external joinery. There are no specified requirements for dimensional movement of timber species for balconies.

What is dimensional stability?

Dimensional stability (or anti shrink and swelling efficiency) is the ability of the wood to resist dimensional changes as the moisture conditions change. Data is presented in the Handbook of hardwoods (1972) and the Handbook of softwoods (1977).

There are numerous references related to the dimensional stability of acetylated wood that show that at a WPG of 20% the wood is more resistant to shrinking and swelling and is movement class ‘small’. Sources of information include an SHR report to Titanwood (2006) and Hill (2006). Research shows that the higher the WPG of acetylated wood the higher the anti-shrink efficiency. This improvement in dimensional stability was postulated to be a result of the hygroscopic hydroxyl groups being replaced by acetyl groups that are less hygroscopic.

Handbook of hardwoods Handbook of softwoods	Indicative movement class	Tangential and radial movement from 90%RH and 60%RH
Western red cedar	small	1.9% and 0.8%
American white oak	medium	2.8% and 1.3%
Siberian larch	small	1.7% and 0.8% data for *Larix decidua*
Sapele	medium	1.8% and 1.3%
Douglas fir	small	1.5% and 1.2%
Scots pine	medium	2.1% and 0.9%
Acetylated wood*	small	-

* Sources of information are considered in this document

SHR report 3.330-366 (2005) details the performance of wood coatings on panels of envelope acetylated (<20%) Scots pine sapwood after almost 10 years of outdoor exposure. The dimensional changes with acetylated wood were noted as being reduced by 80% compared to the untreated Scots pine sapwood. Less shrinking and swelling of the substrate offers a significant opportunity to reduce stresses on exterior wood coatings. The panel trials reveal that after 9.5 years of weathering in the Netherlands at 45° facing south the coated acetylated wood is performing well compared to the untreated wood which has lost most of its coating. The transparent coatings on acetylated wood were failing as result of the coating itself whilst the opaque white coatings were performing well. Adhesion tests revealed good adhesion on the acetylated wood independent of the water uptake. As with untreated wood vulnerability of acetylated wood to blue stain fungi is noted and maintenance of coatings is recommended to avoid this issue.

Structural properties and glue performance as laminated material

<u>Evidence for the mechanical properties of acetylated wood</u>

There is evidence in the scientific literature that the strength properties of timber are not affected by acetylation as measured by bending tests to determine MOE and MOR on small clear specimens. Hill (2006) in his review of the subject cites work from different laboratories that found slight decreases in strength properties for pine and slight increases for spruce samples of small clears. Jorissen et al (2005) report a study of the strength properties of 4m long boards of acetylated radiata pine measured using four point bending test according to

EN408. They concluded that the acetylation of radiata pine in structural size pieces does not significantly affect the modulus of elasticity in bending. The modulus of rupture was slightly lower than the untreated material. They noted the relationship between MOE and MOR was the same for the untreated and acetylated material. They recommended a grading system be employed after acetylation to overcome the fact that the characteristic value dropped by 35% due to the great variability in the strength properties.

Evidence for the glue laminated performance of acetylated wood

The acetylation process reduces the number of hydroxyl groups that are available in wood by reacting them with acetic anhydride to form the ester bond. The loss of hydroxyl groups makes the surface more hydrophobic and adhesives that are commonly used for bonding wood may no longer be suitable (Hill 2006). Effectiveness of a wide range of wood adhesives were tested for shear strength by Vick and Rowell (1990) and they conclude that those relying on hydrogen bonding with hydroxyl groups (e.g. UF resins) performed less well on acetylated wood whilst others such as polyurethanes performed very well.

British Standards for life expectancy

As there are no existing standards specifically for acetylated wood it is sensible to consider a natural durability class. This is noted as a departure from established UK custom and practice. BS 8417 (2003) links the durability requirement for external joinery to a service life. For exterior joinery a 15, 30 or 60 year service life is satisfied by choosing as a minimum a timber of natural durability class 4, 3 or 2 respectively. In addition, the service factor based on safety and economic factors is Class D where collapse of structures would constitute a serious danger to persons or property thus natural durability or preservative treatment is essential.

Considering the above the durability of Accoya™ is capable of delivering a 60 year working life balcony which is in excess of the natural durability of the selected joinery timbers considered in this document. For exterior joinery applications the enhanced dimensional stability of wood acetylated to 20% WPG is capable of extending the working life of coatings and thus the overall joinery product.

The evidence shows that the performance of Accoya™:

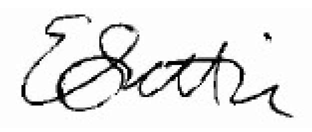
- Is resistant to attack by basidiomycetes, soft rot, insects
- Improves dimensional stability and enhances the performance of coatings
- Has a requirement to protect against blue stain in service through a maintenance and care package

We advocate best practice design principles for balconies to ensure fitness for purpose with features that protect the balcony by minimising water ingress into timber and maximising water shedding, thus maximising the overall service life of the components. Features of best practice design are evident in the drawings supplied for the proposed balconies at the Berkeley Homes development at Holborough Valley, Snodland, Kent. These include:

- Structural grade timber (C30 laminated material)
- Priming or full factory finishing all components
- Attention to holes predrilled for fixings and the sealing of them after installation with mastic
- Corrosion resistant fixings – either galvanised or stainless steel (screws, threaded bars, fixing plates)
- Leadwork protection of timber standings

We consider that a balcony prepared from Accoya™ (a permeable timber species that is acetylated through the cross section to 20% WPG), will show significantly improved coatings performance properties. If the structure is designed by a qualified structural engineer, built to the principles of best practice (primarily to minimise moisture ingress and to facilitate drying) using appropriate glues, fixings and factory finished quality coatings such as Sikkens or Teknos, installed by competent contractors and linked to a maintenance and care package such as the Sikkens Sentinel Plus scheme or the Teknos-ICI Timberplan scheme it will provide a balcony of outstanding durability and stability that would meet a 60 year design life.

Yours sincerely



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